Roundabout Design 101:
Roundabout Capacity Issues

Part 2
March 7, 2012

Presentation Outline – Part 2

- Geometry and Capacity
- Choosing a Capacity Analysis Method
  - Modeling differences
    - Capacity
    - Delay
    - Limitations
- Variation / Uncertainty in Prediction
- Examples
- Staging Construction to Match Volume Increase

Geometry Strongly Affects Capacity

Comparison of Traffic Signals and Roundabouts In Terms of How We Add Capacity

Traffic Signals

- A combination of geometry and timing plans
- Capacity added in lane increments

Roundabouts

- Rely primarily on geometry
- Subtle changes produce the largest benefits when conditions appear unmanageable

Geometry Affects Capacity

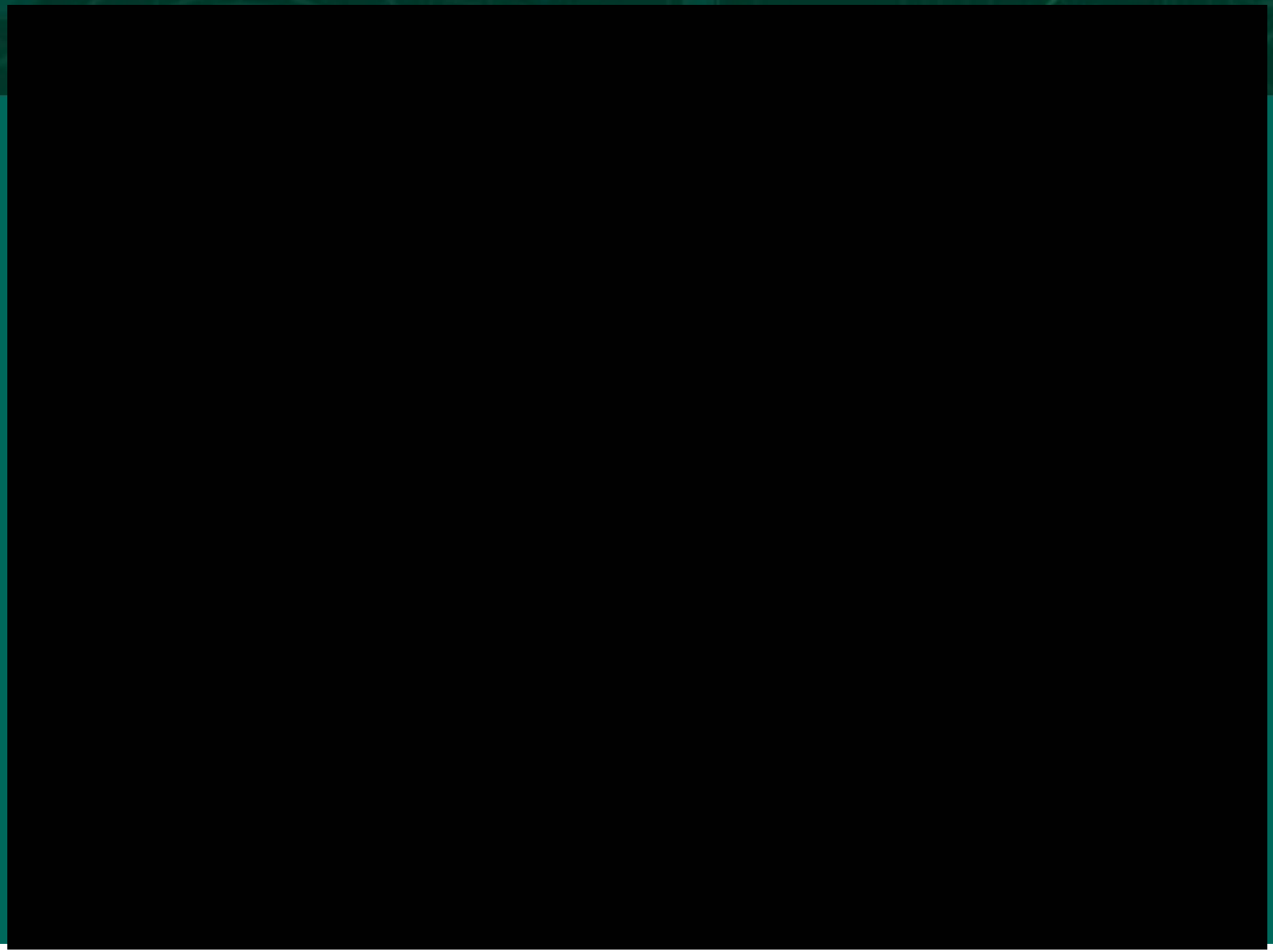
Poor Geometry

Before

Improved Geometry

After

Roundabout Performance with Tidal Flows



Types of Capacity Models for Modern Roundabouts

Linear Regression (strong empirical basis in U.K.)

- Arcady, RODEL – TRL Report 942 equations

Gap Acceptance

- Sidra
- HCM 2010

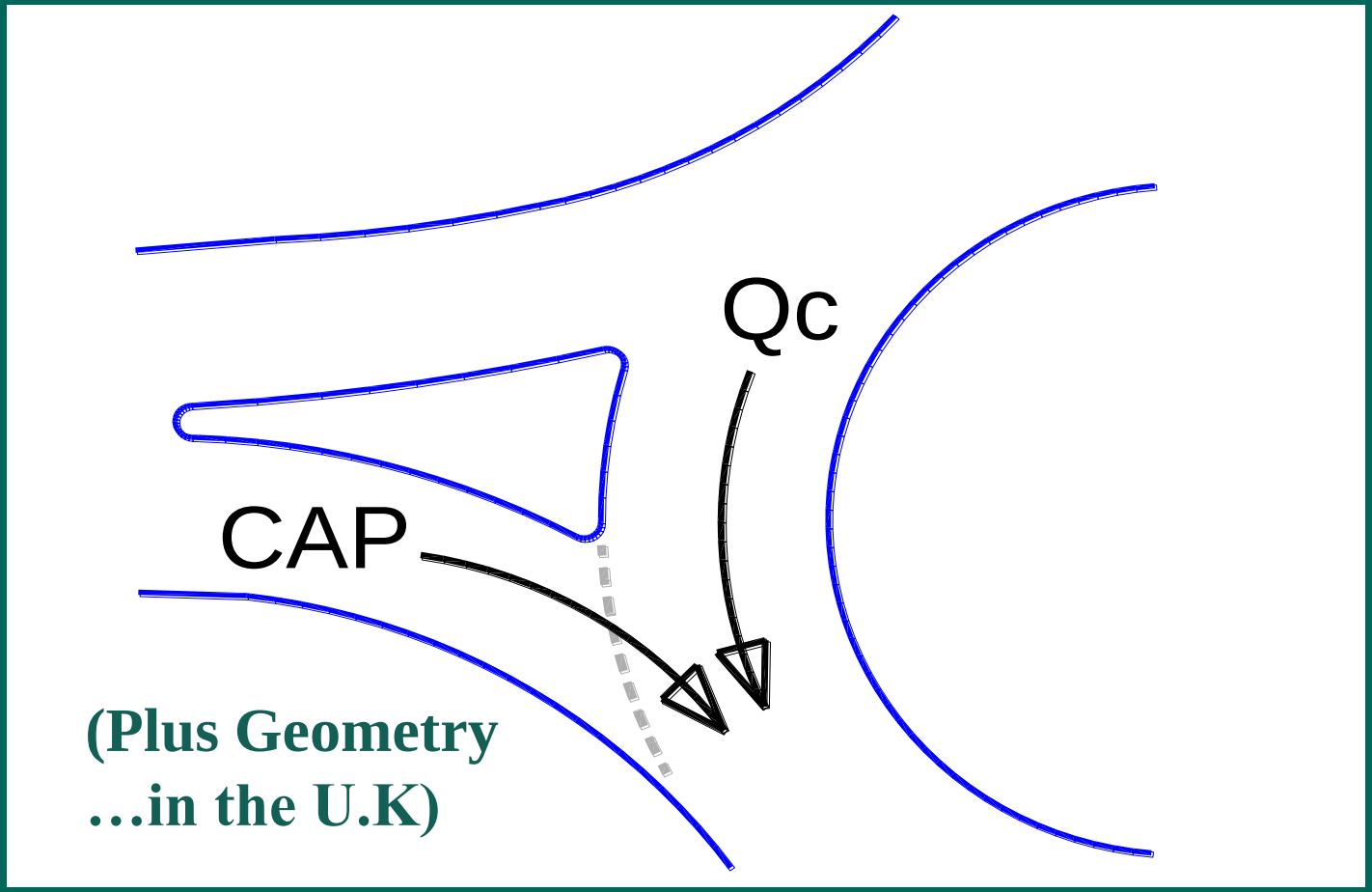
Theoretical Models (less empirical basis):

- Vissim, Paramics, Synchro, Aimsun

New FHWA Guide
Chapter 4 – Selection of Analysis Tools

Application	Typical Outcome Desired	Input Data Available	Potential Analysis Tool
Planning-level sizing	Number of lanes	Traffic volumes	Section 3.5 of this guide, HCM, deterministic software
Preliminary design of roundabouts with up to two lanes	Detailed lane configuration	Traffic volumes, geometry	HCM, deterministic software
Preliminary design of roundabouts with three lanes and/or with short lanes/flared designs	Detailed lane configuration	Traffic volumes, geometry	Deterministic software
Analysis of pedestrian treatments	Vehicular delay, vehicular queuing, pedestrian delay	Vehicular traffic and pedestrian volumes, crosswalk design	HCM, deterministic software, simulation
System analysis	Travel time, delays and queues between intersections	Traffic volumes, geometry	HCM, simulation
Public involvement	Animation of no-build conditions and proposed alternatives	Traffic volumes, geometry	Simulation

Capacity of An Approach



HCM Multilane and Critical Lane Capacity

1. Multilane entry conflicted by one circulating lane

- Apply single-lane capacity model to critical approach lane

$$c = 1130 \cdot \exp(-0.0010 \cdot v_c) \quad (4\text{-}4)$$

where

$c = q_{e,max}$ = entry capacity (veh/h)

$v_c = q_c$ = conflicting circulating traffic (pcu/h).

1. Multilane entry conflicted by two circulating lanes:

- Apply NCHRP 572 multilane capacity model to critical approach lane

$$c_{crit} = 1130 \cdot \exp(-0.0007 \cdot v_c) \quad (4\text{-}7)$$

where

$c_{crit} = q_{e,max,crit}$ = capacity of the critical lane (pcu/h)

$v_c = q_c$ = conflicting flow (pcu/h)

Advantages of HCM Model

- Familiar to analysts with stop-controlled intersections
- Straight-forward and outlined in the 2010 HCM
  - ability to analyze two lane roundabouts
- Able to calibrate HCM equations by using only one other site's gap parameter data
- Based on U.S. data

HCM Limitations

- Queue and delay predictions overlapping time slices require iterative analysis (limit ~ 0.85 v/c)
- Closely spaced intersections
- Three lane entries
- No geometric variation for complex design
- Need to look back at built roundabouts to see what HCM would have revealed for capacity requirements – many examples to choose from

Which Method to Use?

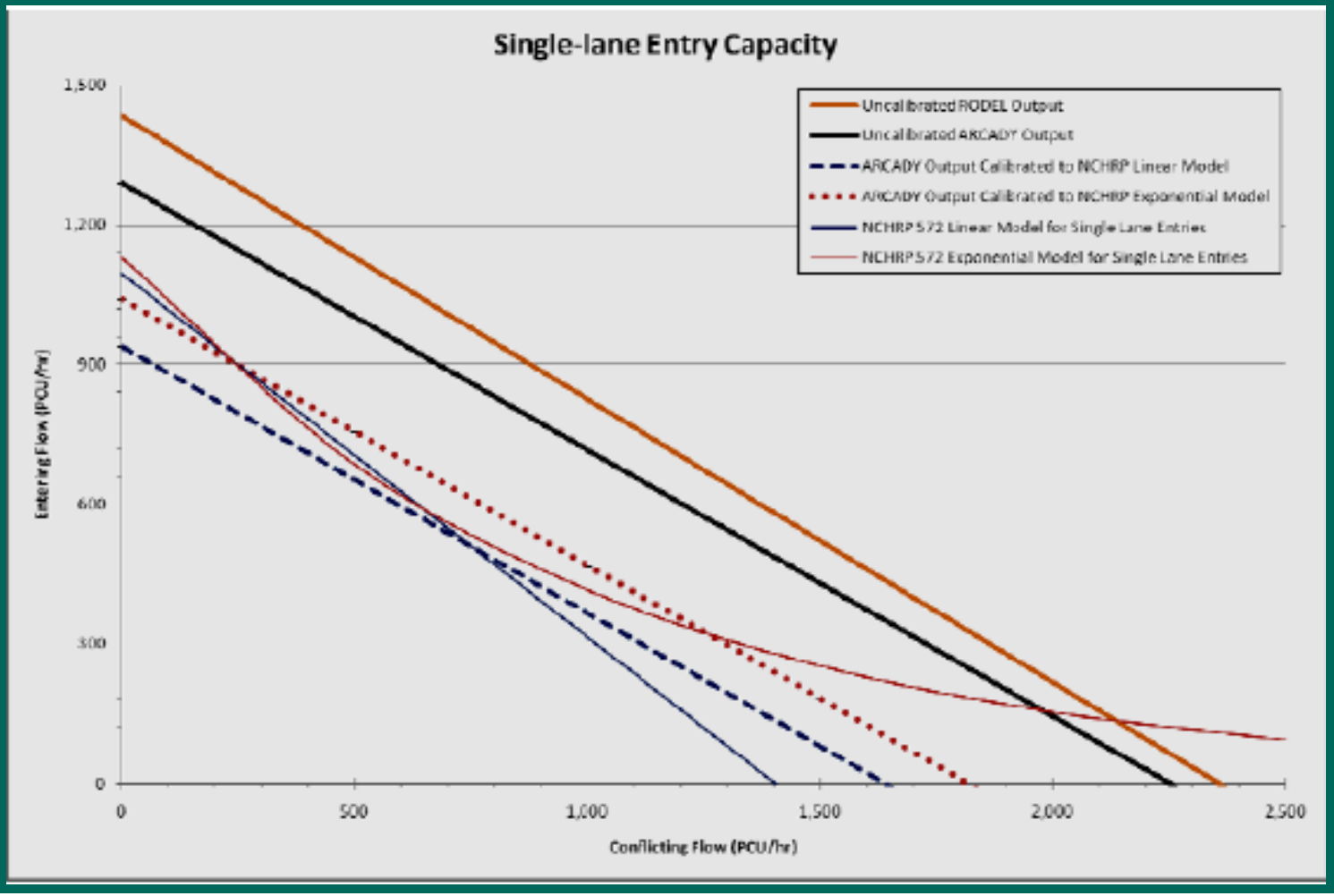
- HCM method is becoming customary, but there are limitations…
- How to meet agency's desire for HCM model results but still provide confidence in the analysis?

Multiple analyses are becoming the norm to demonstrate confidence in the prediction.
* Especially for complex designs

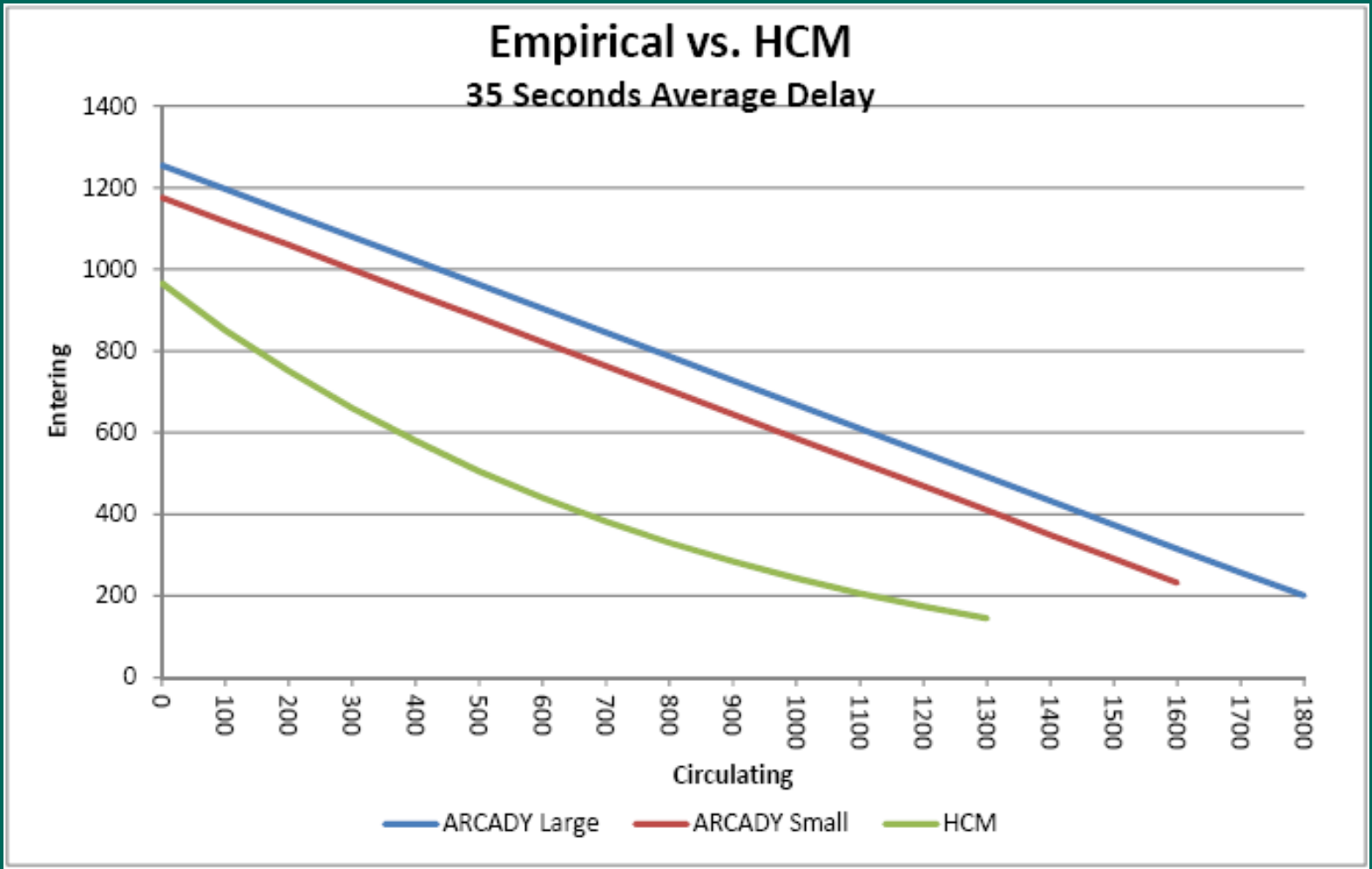
Current Trend Among Analysts

- Use multiple models to report a range of results
- Conduct sensitivity testing by:
  - Varying traffic flow
  - Calibration using out-of-state values
  - Consideration of staged design…1st 10 years…
- Other states are responding similarly, e.g. GA DOT mandates HCM but allows for Sidra and Arcady results to supplement

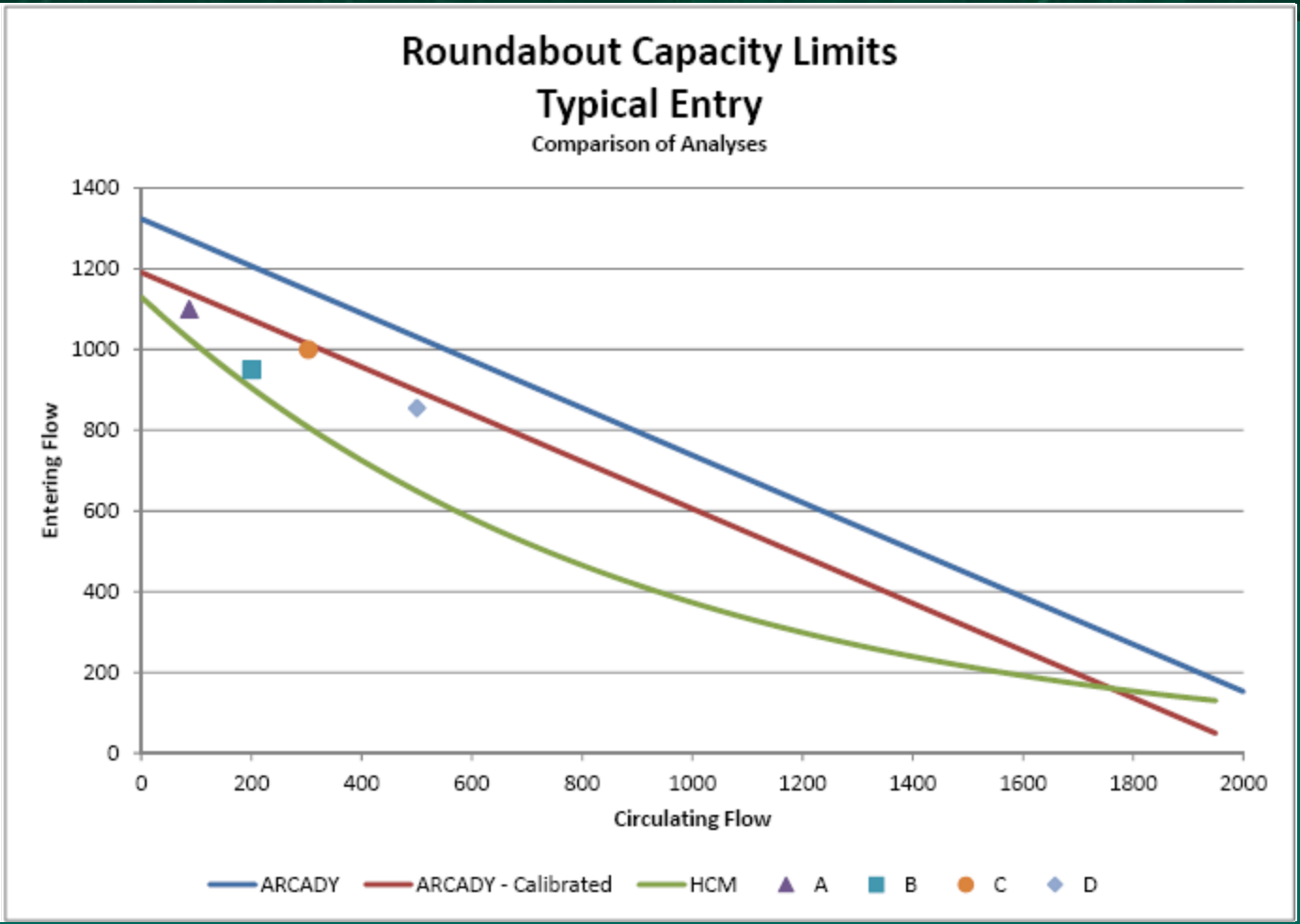
Variation in Capacity Prediction Between Models

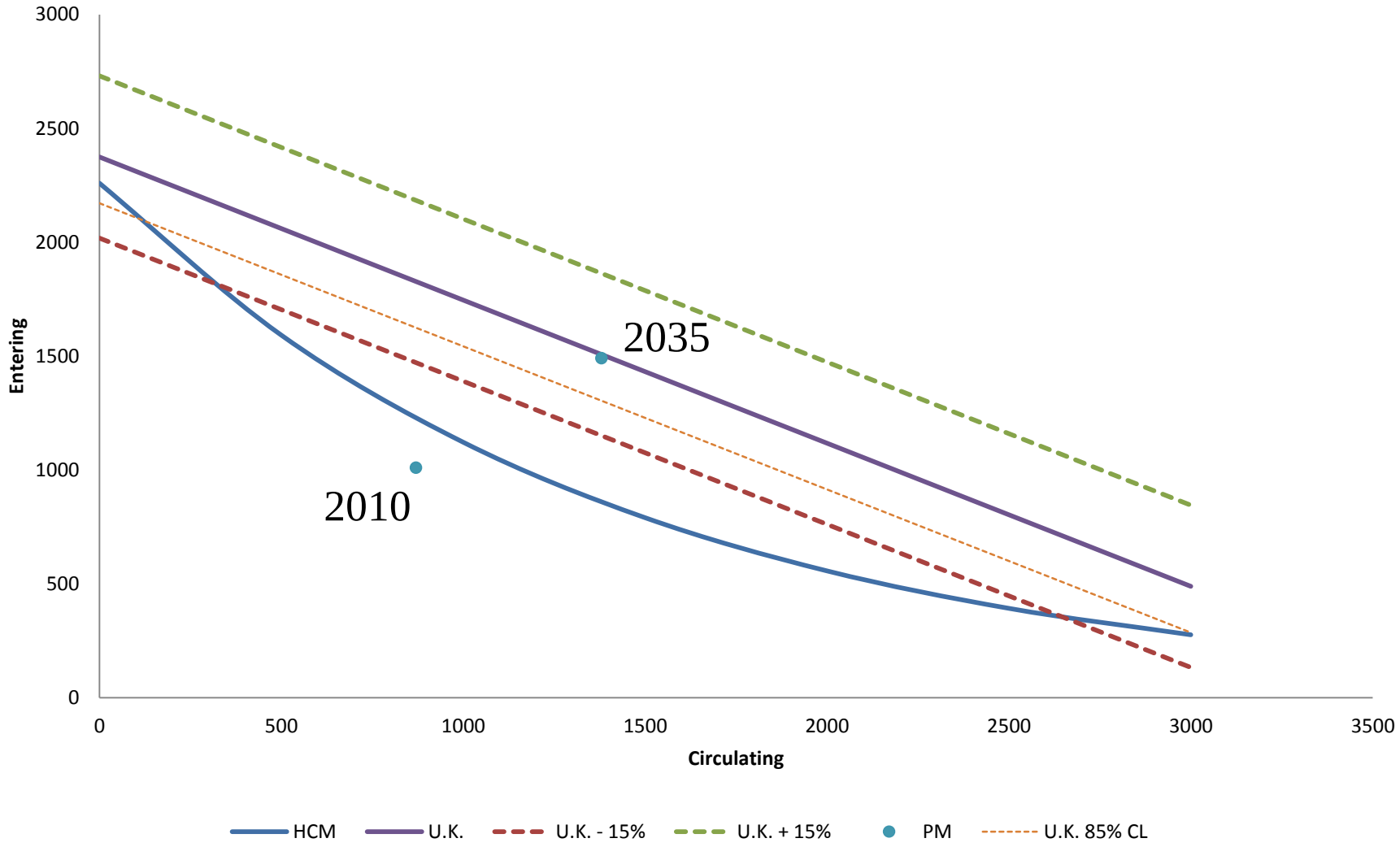


Variation in Delay Prediction Between Models



Example Comparison of Analyses

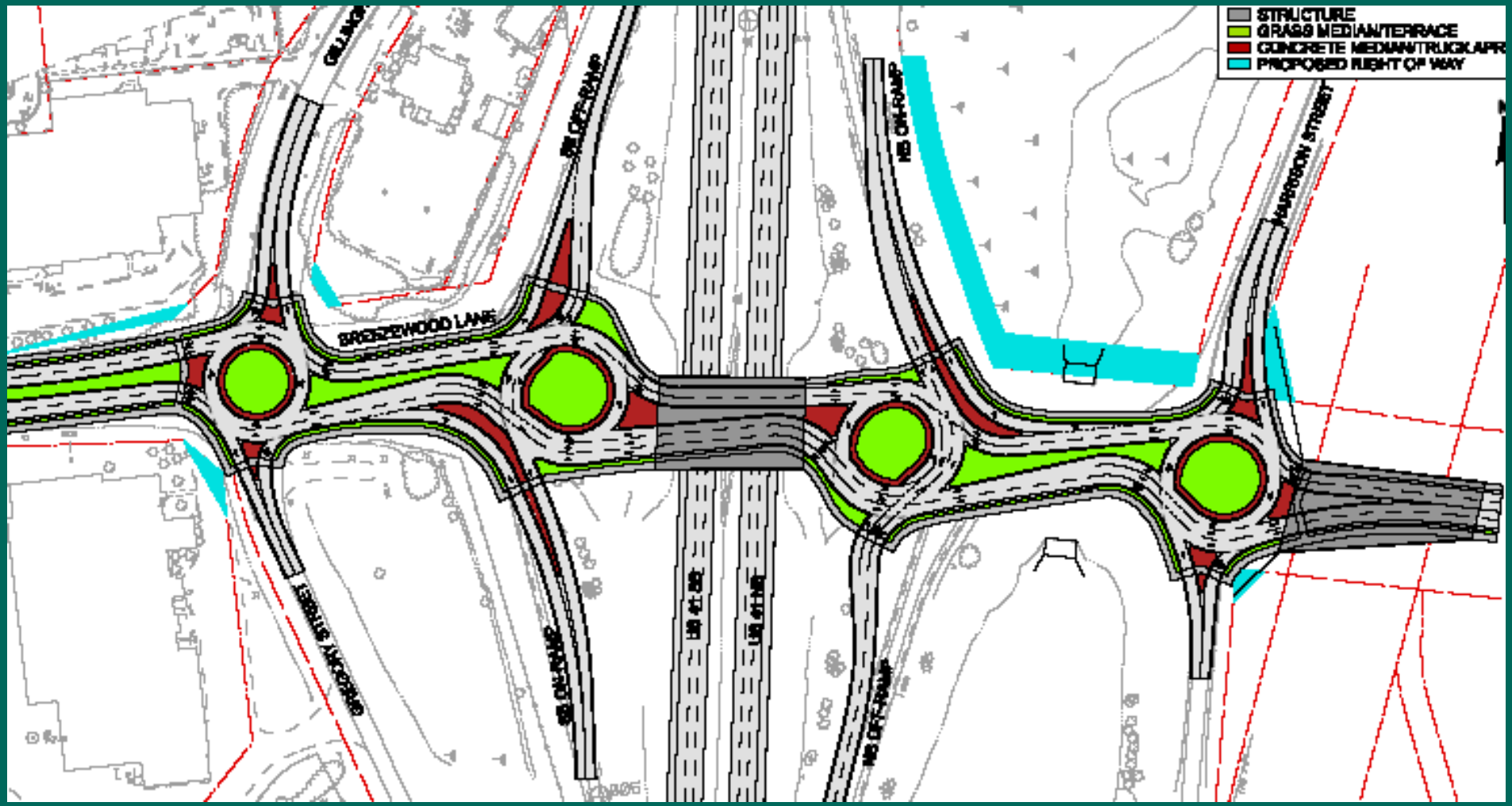



3000
2500
2000
1500
1000
500
0
Entering
0
500
1000
1500
2000
2500
3000
3500
Circulating
2035
2010
HCM
U.K.
U.K. - 15%
U.K. + 15%
PM
U.K. 85% CL

How Certain are the Inputs?

- Traffic projections
- Land development / re-development
- Operation prediction models
- Driver behavior
- Vehicle characteristics
- Existing traffic flows – often the only indisputable input

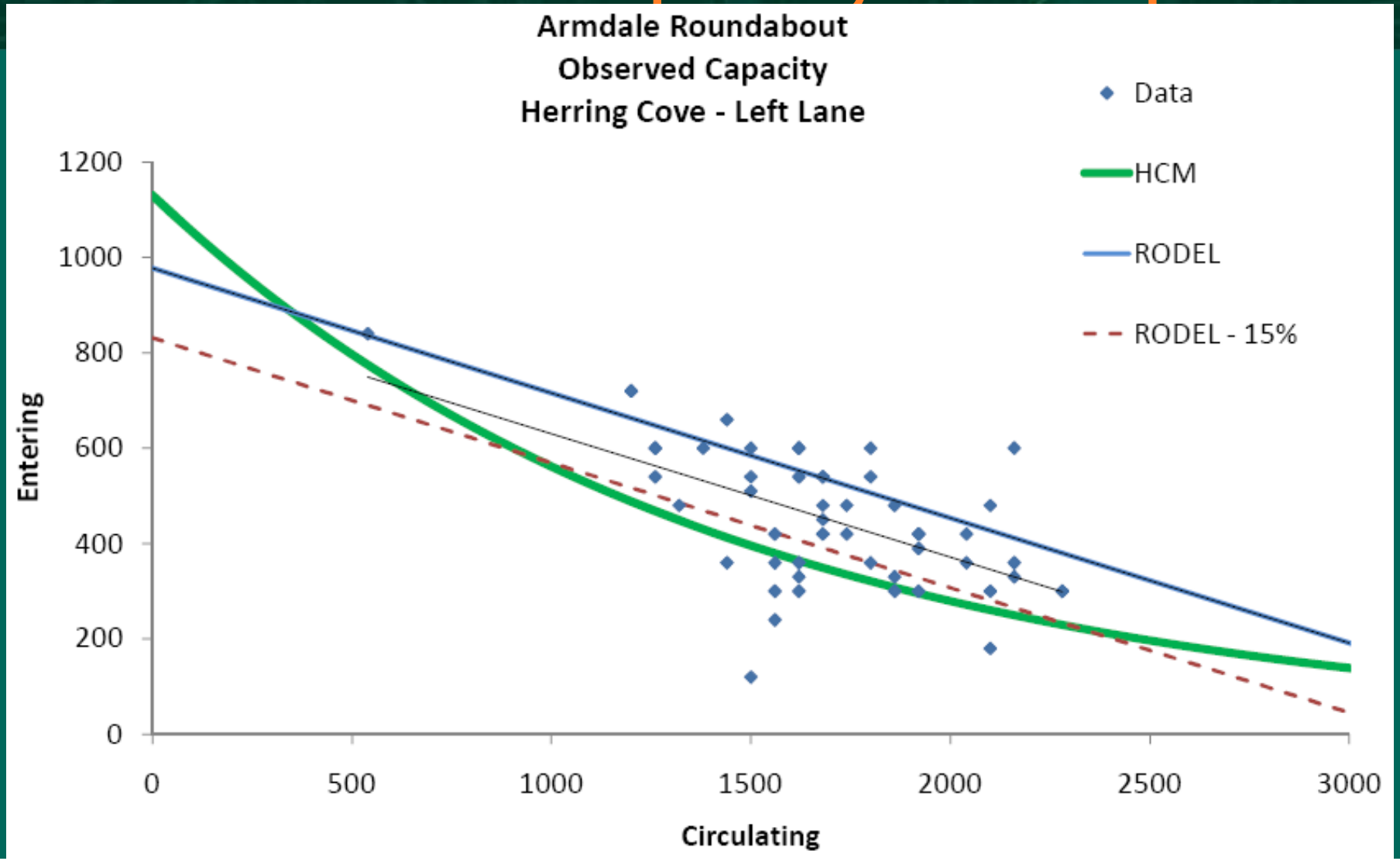
The Complexity Increases as Capacity is Underestimated…



Field Measurement of Capacity

- Entry must have sustained queuing
  - Minimum 4-6 vehicles
- Count entering and circulating volumes
- Capture a wide range of flow variations
- Look for features that influence flow

Observed Capacity Example



Why Build Single-Lane Initially?

- Operational simplicity, especially if first roundabout in area
- Cost is lower initially (although higher in total)
- Single-lane roundabouts exhibit better safety than multi-lane roundabouts
- Without volumes to justify multi-lane, more potential for drivers to ignore lane markings – resulting in higher speeds

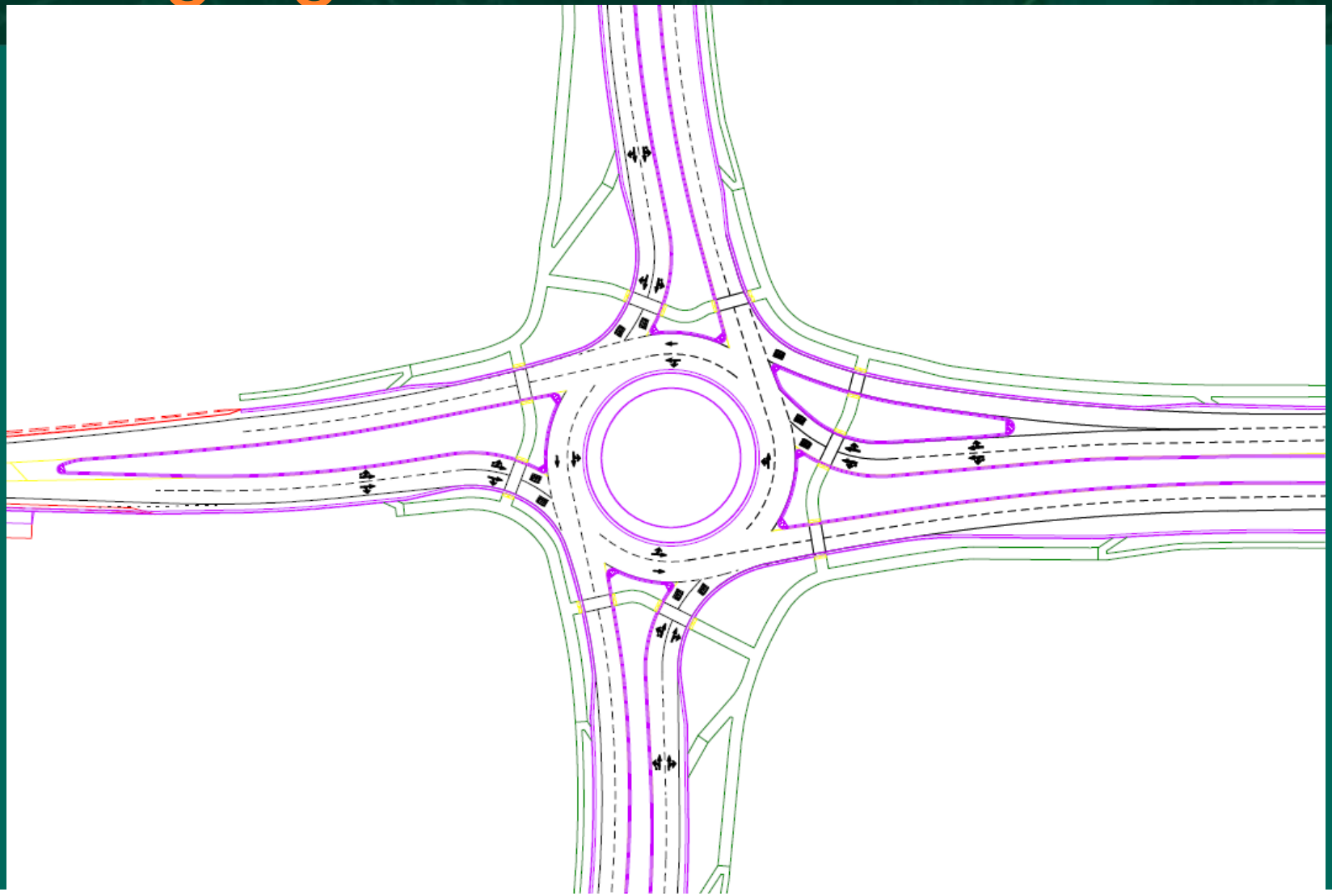
Timing of the Ultimate Layout?

- Can eliminate the need to reconstruct intersection when road corridor is widened

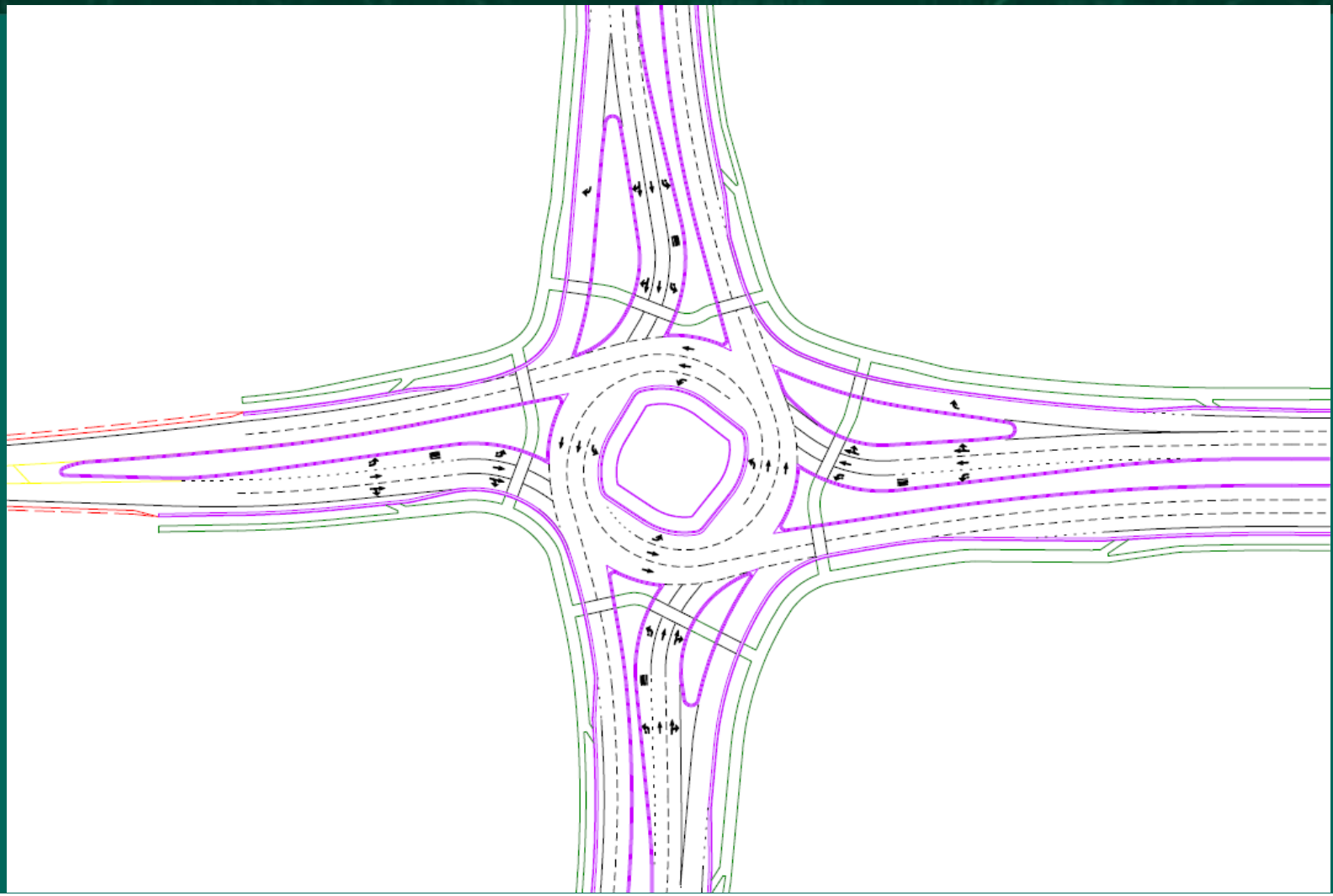
2 Lanes to 1
Exit Merging

20 Year Roadway, 75 Year Bridge

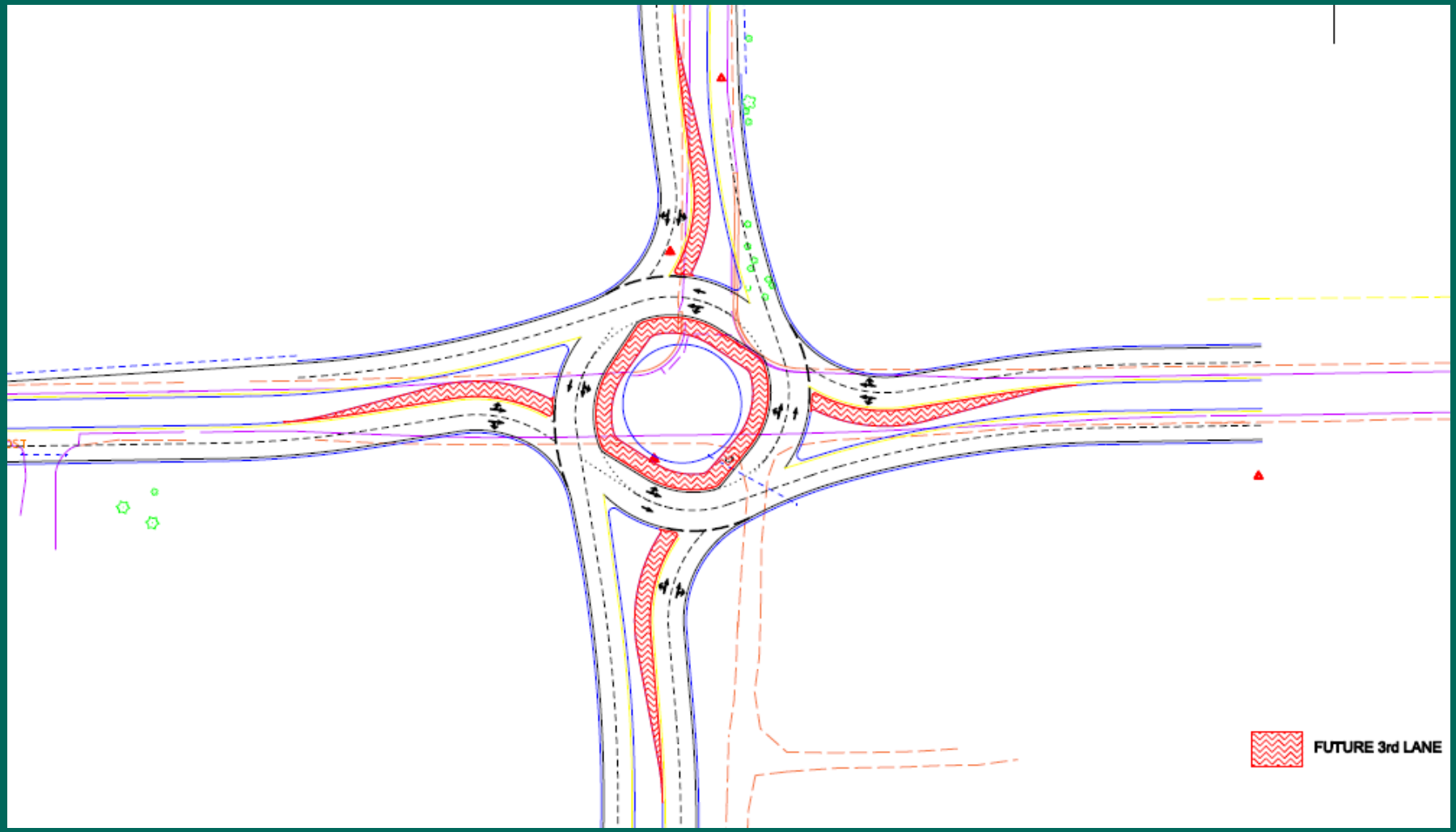
Staging Inward – 2 Lane, Build



Staging Inward – 3 Lane, Ultimate



Staging Inward

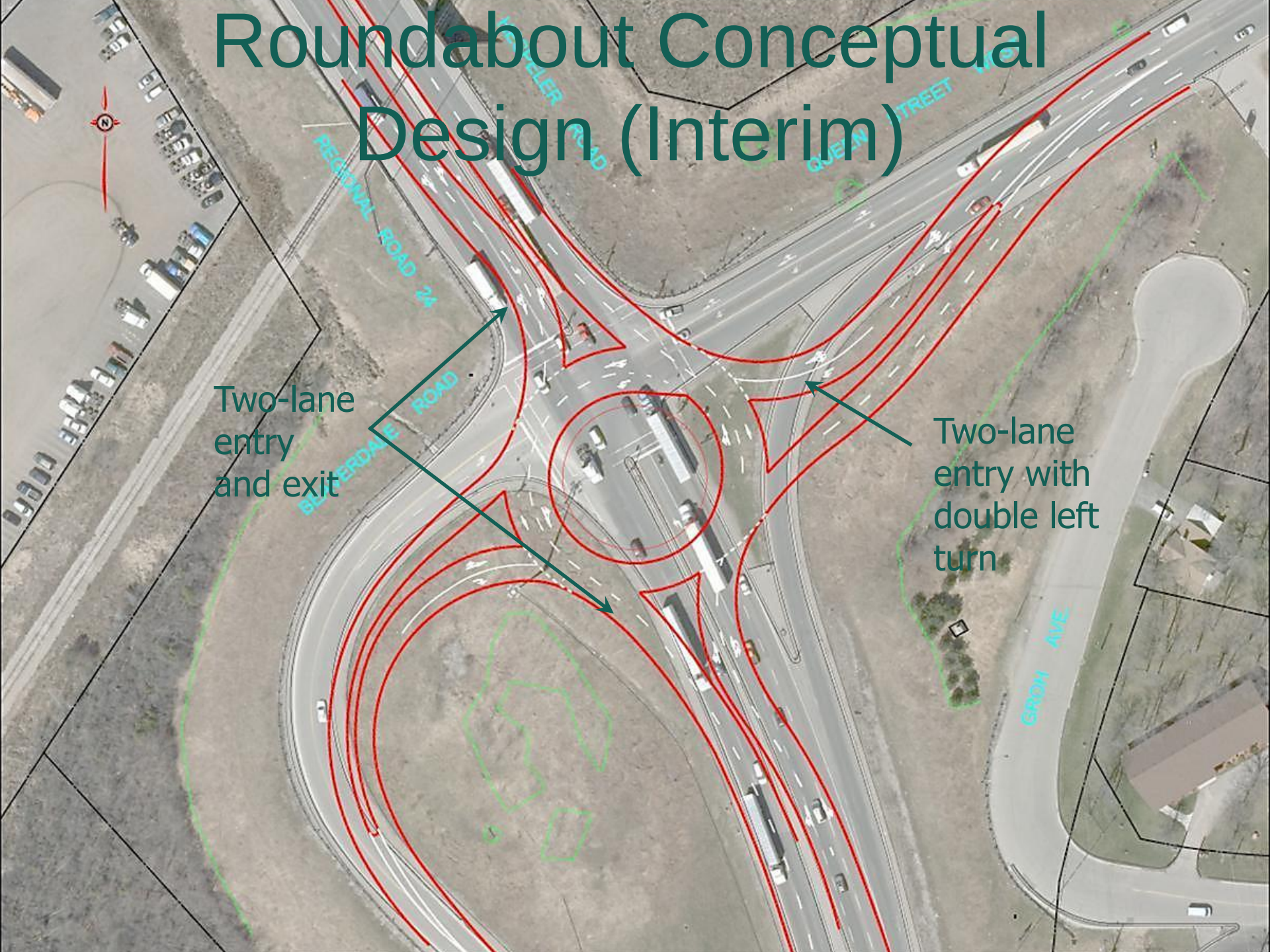


Staging Outward

- Build final central island and splitter islands and widen outward

- Advantages:
  - Smaller roundabout initially
  - Easier to design, and some markings can often be salvaged
  - Simpler with non-symmetric widenings (i.e. northbound only, instead of northbound and southbound)
  - Lower initial cost

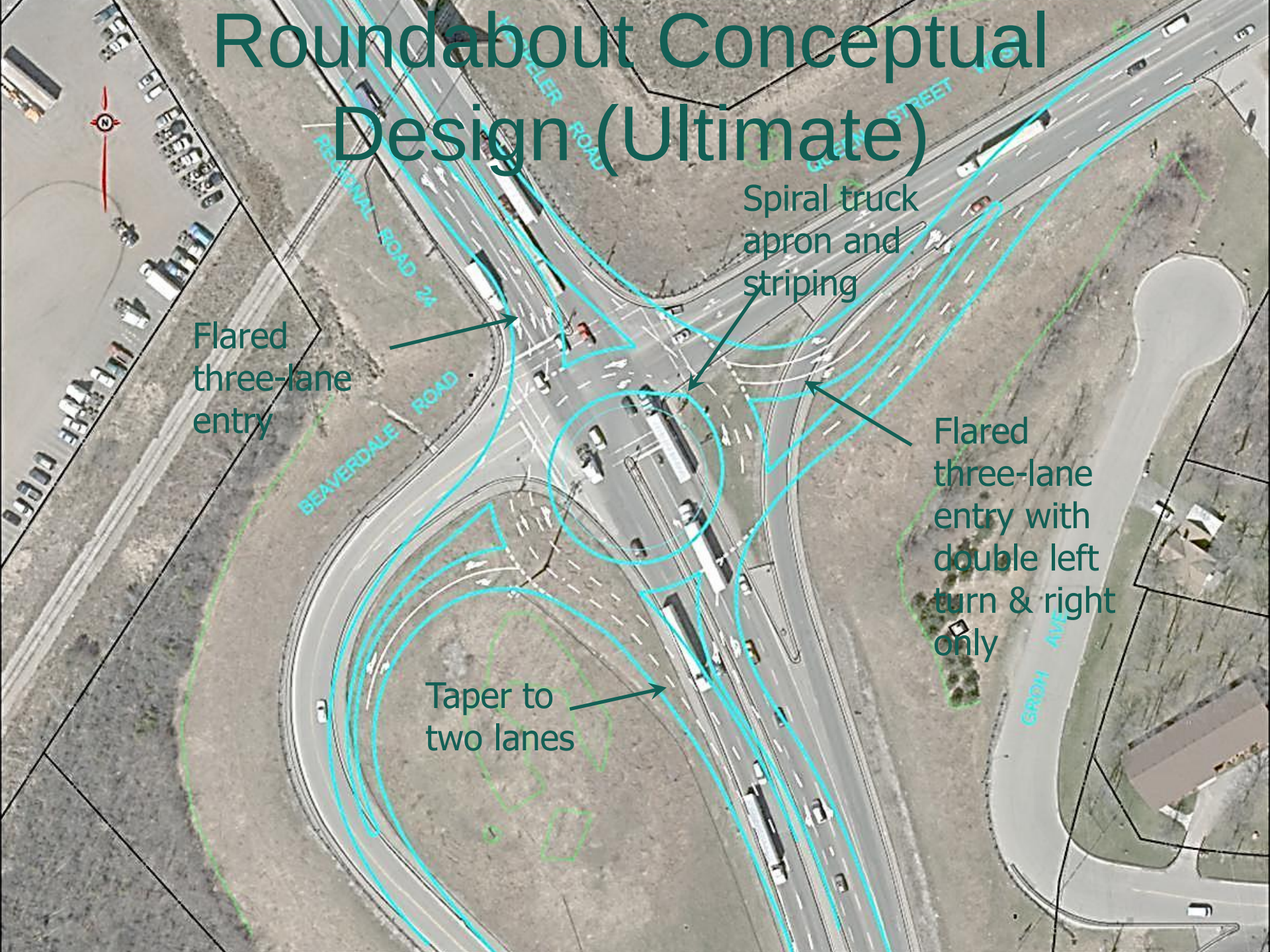
Roundabout Conceptual Design (Interim)



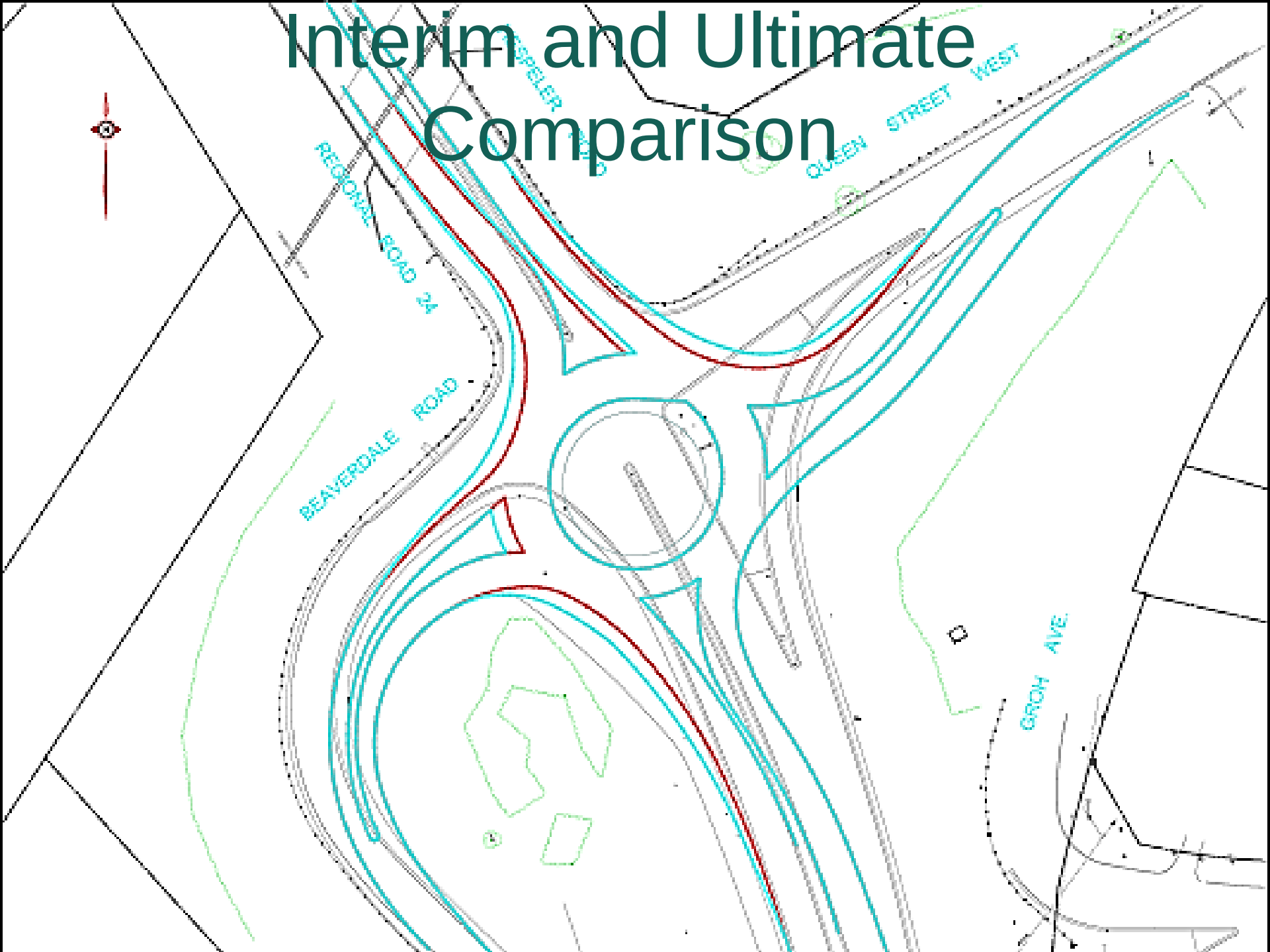
Staging Outward

- Disadvantages:
  - Adjoining properties disturbed twice instead of once
  - Relocation of drainage features, sidewalks and bike lanes
  - Higher overall cost

Roundabout Conceptual Design (Ultimate)



Interim and Ultimate Comparison



Theoretical Models

What situations are appropriate for simulation?

- Typically used as an additional capacity analysis tool (not primary)
- Interaction between roundabouts and signalized intersections
- Merging and weaving analysis
- Roundabout system interaction
- Very effective tool for public presentations

Micro-Simulation Example

“Seeing is Believing?”

- Be cautious of “Seeing is Believing” attitude
- Have seen VISSIM simulation with pedestrians walking through cars.
- Have seen vehicles drive through trucks
- Have seen two semi-trucks simultaneously enter a roundabout with out encroaching on adjacent lanes (not realistic)
- Use evidence based approach; Actual field statistics for engineering work. Statistics describe empirical data (reality)

Including Simulation with Analysis

Advantages:

- Typically used as an additional capacity analysis tool (coupled with a design tool like Arcady)
- Interaction between roundabouts and signalized intersections
- Merging and weaving analysis
- Roundabout system interaction
- Very Effective tool for public presentations

Disadvantages:

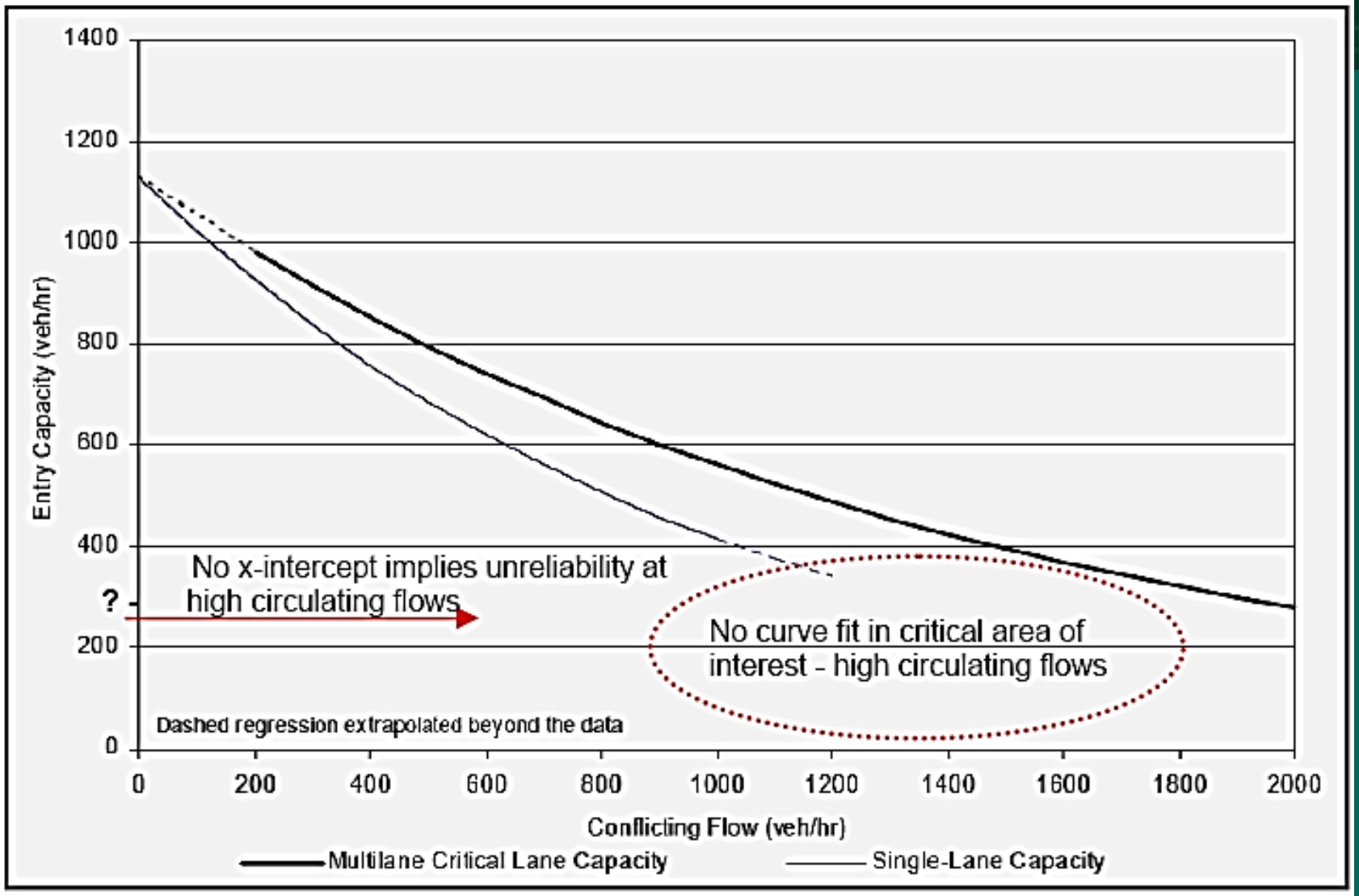
- Calibration is very difficult
- Uniformity among users is elusive (too many bells…)


Ourston
Roundabout
Engineering

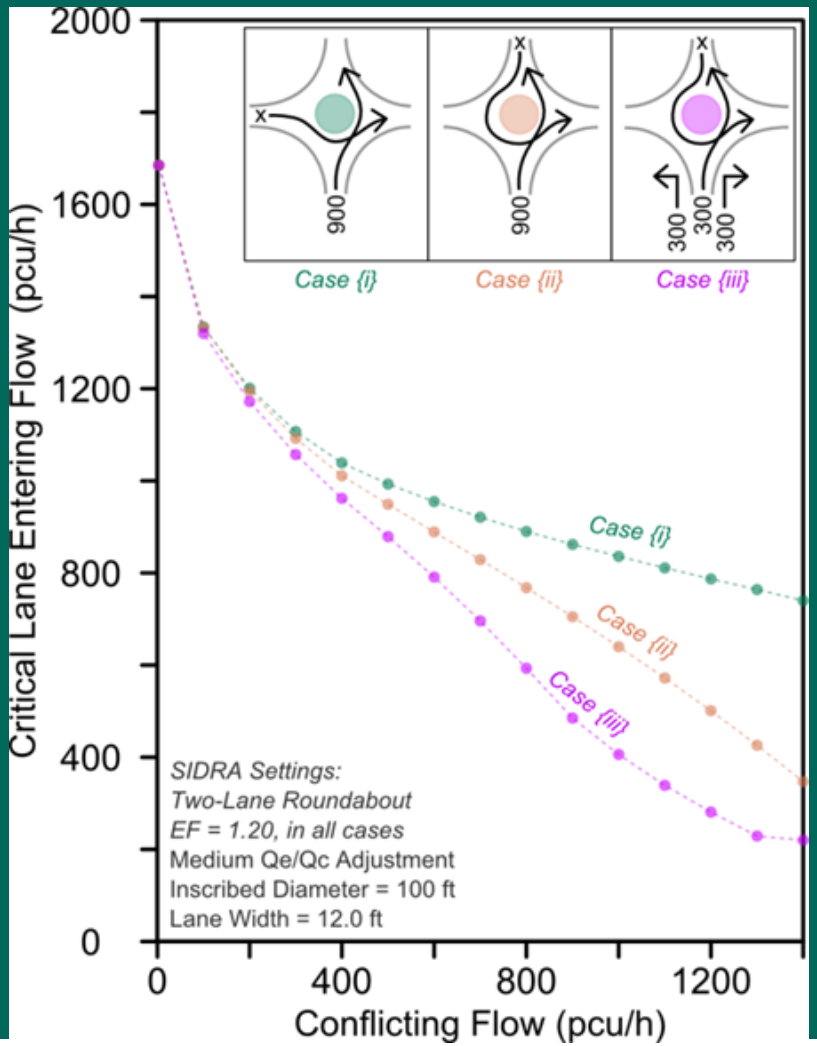
Alternative Capacity Analysis Methodology

- Empirical
  - ARCADY
  - RODEL
- Gap-Acceptance
  - Sidra
  - HCM
- Micro-Simulation
  - Vissim, Paramics, Aimsun

U.S. Capacity Model



Capacity Models in SIDRA



- Origin-Destination patterns affect capacity results
- *These three cases show ***extreme*** examples to illustrate O-D effects

1. Capacity of South Leg was analyzed, varying the number of turning vehicles while maintaining 900 vehicles entering
2. Circulating volumes were increased for either the upstream thrus or opposing lefts, as depicted on the graph, to create conflicting flows in front of the South Leg
3. Capacity results for the critical entering lane of the South Leg were recorded as entering flow and plotted against the conflicting flow from Step 2

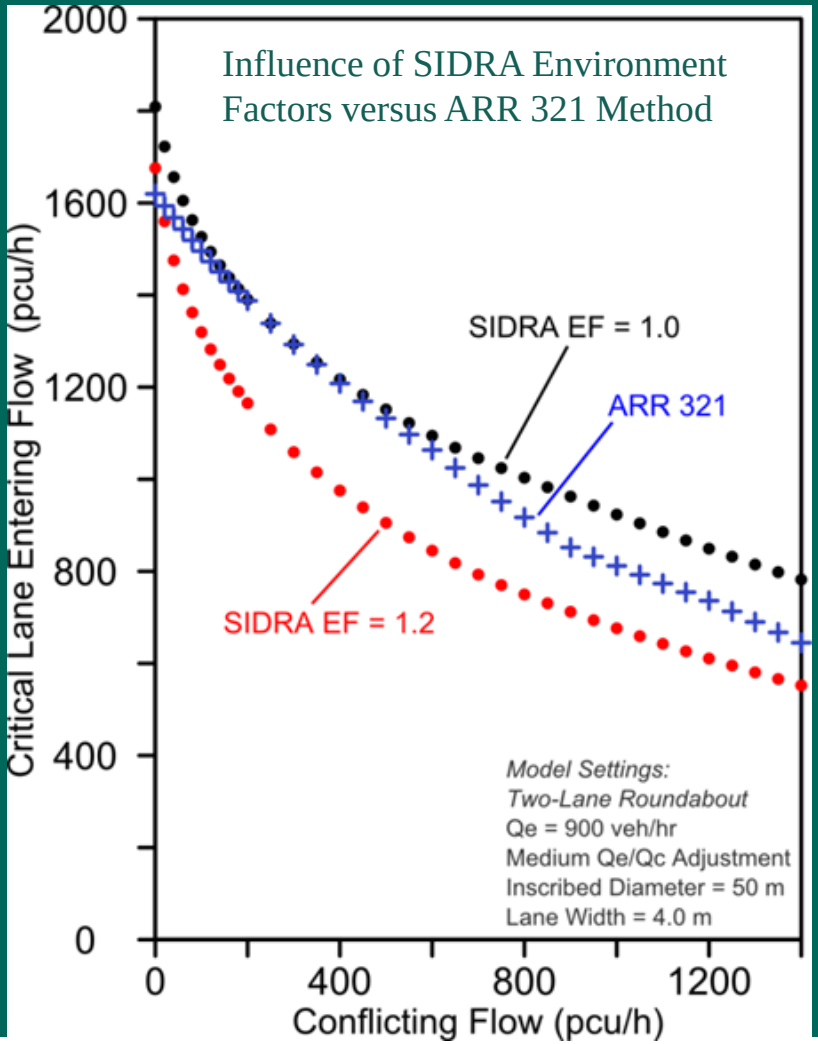
Delay Models in SIDRA

- Two standard delay models for roundabouts
  - SIDRA Standard Delay
    - ***Delay results in summary tables include geometric delay***
    - Can obtain “Stop Line” delay from detailed output, which is claimed to be comparable to control delay reported by HCM 2010 Delay Formula
  - HCM 2010 Delay
    - Delay is calculated with HCM 2010 Delay Formula
    - ***Delay results in summary tables are Control Delay, geometric delay is not included***

SIDRA Calibration Options

1. Environment Factor
   - (1.0, 1.1 and 1.2…2.0; higher values imply more restriction)
2. Entry/Circulating Flow Adjustment
   - High, medium and low settings
3. Critical Gap and Follow-up Headway

SIDRA Calibration Options



1. Environmental Factor (EF)

- EF adjusts critical gap and follow-up headway parameters to account for general roundabout environmental terms
- Can only be changed when using SIDRA Standard Capacity Model
- User guide suggests using EF 1.2 to calibrate capacity to observed US data

SIDRA Calibration Options

2. Entry/Circulating Flow Adjustment
   - Adjustment of critical gap and follow-up headway parameters to avoid underestimation of capacities at low circulating flows
   - None, Low, Medium, High
     - None results in lowest capacity results
     - High results in highest capacity results
   - Default for SIDRA Standard Capacity Model is Medium
   - Default for US HCM 2010 Capacity Model is None

3. Critical Gap and Follow-up Headway
   - If local values from field data are known, parameters can be changed in the Gap Acceptance window

Corridor Widenings

- Flared entries at roundabouts extend 30-300ft. upstream
- Taper and parallel deceleration lanes at signalized intersections require 450-600ft.
- Because of these extensive lengths, widening the entire corridor under traffic signal control often costs little more
- The ROW impacts may be the same because of utilities

Variation in Capacity Prediction Between Models

- Show comparison graph from TOPS report